Failure of Cast Iron buried Water Mains

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Abstract

The problem of aging cast iron water pipes manifested in breaks and leaks in distribution systems is common to all municipalities throughout the world. Based on limited literature review, here we indentify and study the various failure patterns and the causes leading to such failures. The different failure types are broadly classified and tabulated.

1. Introduction

The water distribution systems all over the world experience hundreds of issue regarding failure of the pipes in the network both major and minor. It has been estimated that approximately 25% of the water in the distribution systems is lost due to pipeline leaks. Based on the study we understand that grey cast iron pipes are the one most prone to failure, corresponding to more than 85% of the total failures. Most of the cast iron pipelines are old pipes, more than 60 years old, with considerable strength loss due to aging and corrosion resulting in higher incidence of failures.

2. Objective

The objective of the project is to identify different failure modes, causes, and mechanism of the buried cast iron water pipelines mains in general.

3. Results and tabulations

Based on the limited study, we can broadly classify these failures into 3 categories. The failure attributed to corrosion, the failure due to excessive stresses and the failure at the joints. Many times the failure occurs as a combination of different types. The mechanical properties of the cast iron pipe mains are discussed and testing methods are listed by Seica and Packer (2000). Corrosion of the pipe can occur both from inside and from the outside of the pipe. Corrosion is an electrochemical process that results in gradual atonement of the metal and hence the loss of strength of the pipe wall. The pitting failure corresponds to the type where there is localized external corrosion that leads to formation of small 'pitting holes'. Graphitization relates to process where the metal constituents of the pipe degrade, eventually leaving only a carbon shell, which is not as strong as the original pipe hence making the pipe wall vulnerable to bursts.

Corrosive soils are classified by the AWWA (1999), the soils with low pH, low Resistivity and significant presence of sulphate reducing bacteria. Other secondary reasons leading to external corrosion are the stray currents that the pipe conducts from the ground, hydrogen embrittlement resulting from unintended or misapplication of cathodic protection. The failure due to external corrosion has been extensively studied by Doyle et al (1999). The nature of internal corrosion depends of the aggressive water properties and its chemical composition and its interaction with the internal pipe wall. Other type of failure is attributed to excessive hoop or axial stresses resulting from the Ambient temperature differences, Transient conditions leading to 'water hammer' effects, freeze-thaw effects due to changing seasons, soil properties settlements or expansions periodically. The failure at the joints results as a combination of different stress, corrosion conditions.

Table 1: Types of Failure

Failure type	Modes of Failure	Causes of failure	References
Type I Corrosion	Pitting Holes	Corrosive soils(low ph, resistivity), microbiological influence, stray currents, external stress corrosion	Grabinsky et al (2000), Doyle et al (2000), Rajani et al (1996)
	Graphitization	Corrosive soils, hydrogen embrittlement, stray currents, anaerobic bacteria	Doyle et al (2000), Packer et al(2002), Grabinsky et al (2000) Hamilton et al
	secondary effects	hydrogen embrittlement, coating damage, dissimilar soils with different concentrations, stress corrosion	Romer et al (2001), Seica et al (2000)
Type II Stress failure	Longitudinal break/split	Ambient temperature differences, transient conditions, Freeze Thaw effects	Makar et al(1999), Schmitt et al(2006), Doyle et al (2000),
	Tensile break	Thermal stresses, Transient conditions, mechanical stresses, soil swelling/settlements	Makar et al(1999), Schmitt et al(2006), Doyle et al (2000), Rajani et al (1996)
Type III joint failure	Brittle failure (cracking)	graphitization, hydrogen embrittlement, dissimilar metals at joints, coating damage	Doyle et al (2000),, Hamilton et al, Romer et al(2001), Hardie et al(2006)
	connection failure	Defects in welding material, thermal stresses, fatigue weakening, Galvanic reaction at dissimilar metal joints	Rajani et al(1996), Doyle et al (2000)
	Joint burst	Transient conditions, soil swelling/settlements, differential thermal expansion/contraction.	Makar et al(1999), Schmitt et al(2006), Doyle et al (2000)

5. Conclusions

Based on the limited literature review different modes and causes of the failure in grey cast iron buried water pipelines are identified. The study identifies corrosion as the major cause of failure to cast iron water mains. Corrosion control measures greatly reduce the incidence of failure.

6. References

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